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by Novendra Setyawan

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Jaya-Neural Network for Server Room Temperature Forecasting Through Sensor Network

Novendra Setyawan, Muhammad Nasar, Nuralif Mardiyah
Departement of Electrical Engineering, Universitas Muhammadiyah Malang, Malang
novendra@umm.ac.id, nasar@umm.ac.id

***Abstract*—The server room temperature is the primary variable that influenced the server performance. Therefore, forecasting the temperature environment in a server room is necessary to prevent the worst condition. The conventional neural network has been widely used to the forecasting problem even though it can easily trap in the local solution which is the leading research topic recently. The other ways to adjust the weight of the multi-layer neural network is using intelligence optimization algorithm. However, in the existing optimization algorithm, the parameter setting is the main topic to get the best optimization result. In this paper, the implementation of the parameterless optimization algorithm is discussed. Jaya algorithm is proposed to adjusting the weight of the multi-layer neural network in the forecasting of server room temperature. The experimental result shows that Jaya-NN has outperformed than the other optimization, and it can forecast temperature data accurately.**

Keywords—forecasting; optimization, intelligence algorithm; Jaya; Neural Network;

I. INTRODUCTION

A server is a storage place for large amounts of data, such as website data, database, and other data applications that can be accessed via the internet. In high temperature and humidity levels will reduce the performance of Servers, so a device to monitor the temperature and humidity levels is needed to stay maintained [1].

Wireless Sensor Networks (WSNs) becoming a popular topic, since the Internet of Things (IoT) is widely used, which allows the physical devices identified, managed, controlled through a wireless internet connection. The environment, water quality, fires forest, and greenhouse approach through WSNs have been proposed since the growth of the area that must be measured by the sensor [2].

In a monitoring system, the environment variable is measured and showed the data through website real-time. It has been helping people to know the variable of environment surrounding, but this system could not decide whether the condition is good, moderate, or worst. In [2][3], fuzzy logic is proposed to determine environment air quality is very good, good, moderate, bad, and dangerous. However, in a dynamic environment such as temperature in the server room, forecasting is essential to prevent the worst condition of server in the future.

In forecasting technique, there are various ways of predicting data in an hour to hour, day to day forecasting, medium-term forecasting, long term forecasting. Short term forecasting has been proposed in two hours ahead to predict load demand using ANN [4]. In another way, day to day forecasting is offered in [5] using ANN. However, accuracy is the main topic in the forecasting technique.

This paper implemented another approach of optimization technique for server room temperature forecasting. This paper organized in five sections. In section II overview of ANN is presented. Then in section III, data preprocessing and ANN learning optimization is developed. The simulation result shows in section IV. Section V discuss the conclusion.

II. DETAIL PROBLEM FORMULATION

A. *Artificial Neural Network*

Neural Networks is a connected network which the elementary unit of the networks is called neuron. Each neuron contains the input, weight of input, activation function, and the output. Many neurons that are connected to form the structure of a network consisting of several layers are called a multi-layer neural network (MLNN). Generally, MLNN consist of one input layer, one or more hidden layers, and one output layer. The mathematical expression of neuron in input to hidden-layer described in eq (1).

$$Yh_j = f_h\left(\sum_{i=1}^{N} Wh_{j,i}X_i + Bh_i\right) \tag{1}$$

for hidden-layer to output-layer mathematical formulation is described in eq (2).

$$Yo_k = f_o\left(\sum_{k=1}^{N} Wo_{k,j}Yh_j + Bo_j\right) \tag{2}$$

Where X is the input variable, Wh and Wo is the weight of input to hidden-layer and hidden to output-layer, Bh and Bo is the bias in the hidden-layer and output-layer, f_h and f_o is the activation function, then Yh and Yo is the output of hidden-layer and the output-layer. The networks connection can be described in Fig. 1.

The learning process is done by adjusting the weight in the neuron based on error produced by the output node. Backpropagation using least square method is commonly used in MLNN learning process. Several papers have been implementing MLNN in forecasting problem, such as [6] have been the in load electricity demand, in [7] used for forecasting the electricity price and in [8] used for weather forecasting in real-time.

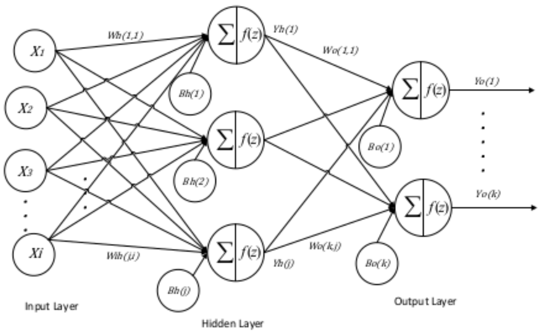

Fig. 1 MLNN structure

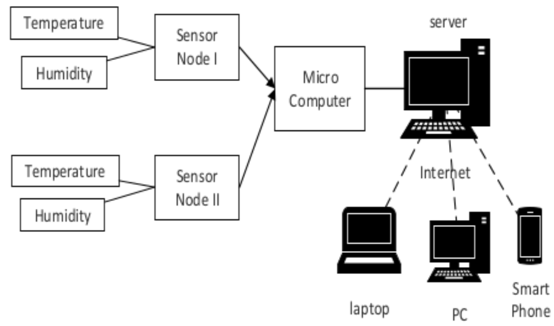

Fig. 2 Proposed Data Acquisition and Monitoring

B. Optimization Algorithm

The learning method is the primary step that affects the accuracy of the training process. Several conventional algorithms have been proposed and developed to train an MLNN in the last years. However, many of them can be trapped in no desirable or local solution; that is far from the optimum or the best solution. Therefore, other kinds of optimization techniques, such as Artificial Intelligence are necessary for training an ANN.

Particle Swarm Optimization (PSO) has been proposed in [9] as a learning algorithm of MLNN by adjusting the weight of the network model to calibrate lens parameter in object detection and measurement of the spherical image. In [10] have been proposed the Genetic Algorithm (GA) to adjusting MLNN weight to forecasting the gas load data in gas load supply system. The Differential Evolution is combined with the backpropagation neural network in time series forecasting. The main reason for the implementation of intelligence optimization algorithm to improve the neural network performance is to avoid the local solution from the classical approach. However, the implementation of the intelligence optimization algorithm, such as PSO in [11] depends on the PSO parameter setting.

This paper proposes a combination algorithm to improve an MLNN using Jaya algorithm, the simple parameterless and robust optimization algorithm to forecast the temperature of the server room.

III. Proposed Method

A. Data Pre-Processing

In this section, the data variable measurement is discussed. The temperature and humidity of the server room are measured by sensor networks. Several sensor nodes are placed in a server room to measure the global condition of the server room environment. Fig. 2 shows how the sensor data is collected by one microcomputer and transmitted to a server through IEEE 802.11ac based communication. The server computer computed the forecaster algorithm, then showed the actual and predicted data on the website. Current and previous time is chosen as the first term input of MLNN, and the second term is the previous temperature data.

B. Jaya-NN

Jaya means success or victory in Sanskrit is a population-based optimization algorithm. Unlike PSO that begins with generating randomize particles and then each particle "fly" in the search space with the velocity update rule, Jaya algorithm directly update the candidate solution in i^{th} candidate, d^{th} dimension variable, and at t^{th} iteration with one equation.

$$\begin{aligned} X_{i,d}(t+1) &= X_{i,d}(t) + A_r - B_r \\ A_r &= r_1\left(X_{best,d} - \left|X_{i,d}\right|\right) \\ B_r &= r_2\left(X_{worst,d} - \left|X_{i,d}\right|\right) \end{aligned} \tag{3}$$

Unlike PSO, Jaya did not have individual learning. Jaya using $X_{best,d}$ and $X_{worst,d}$ to update a new candidate, which is the best and worst candidate solution. The second term in eq (3) is the tendency of a solution to move closer to the best solution, then to avoid the worst solution is in the third term. Then r_1 and r_2 is a random number between [0,1].

In order to measure the forecasting model performance, MAPE (Mean Absolute Percentage Error) is computed in eq (4).

$$J = MAPE(\%) = \frac{1}{N}\sum_{i=1}^{N}\frac{\left|error_i\right|}{Yo_i}\times 100 \tag{4}$$

Where $error_i$ is obtained by substracted between the actual data Yt_i and the output of MLNN Yo_i. MAPE is mean of the forecasting error in 24-hours daily. The performance evaluation is used to evaluate the candidate solution of Jaya in every iteration.

C. Encoding The Candidate Solution

In the previous section, the forecasting model has been described using MLNN model. The accurate forecasting model depends on MLNN weight Wh and Wo, and the bias Bh and Bo. So, in order to get optimum forecast model, the candidate solution of Jaya algorithm is selected as the weight of MLNN.

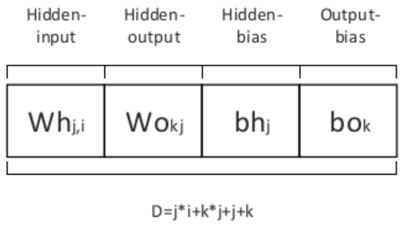

Fig. 3 Jaya-NN candidate solution encoding

Fig. 3 shows each candidate solution correspond to the initial condition weight of MLNN. The D dimension problem of Jaya is identical to the sum of the numbers of weights and biases.

D. Update Best and Worst Candidate

As described in the previous section $X_{best,d}$ and $X_{worst,d}$ is the best and worst candidate solution. Since MLNN learning is the minimization problem of MAPE, the following update mechanism of $X_{best,d}$ and $X_{worst,d}$ is described in eq (5) and eq (6).

$$X_{best,d} = \min\left(J\left(x_{1,d}(t)\right), J\left(x_{2,d}(t)\right), \ldots, J\left(x_{i,d}(t)\right)\right) \quad (5)$$

$$X_{worst,d} = \max\left(J\left(x_{1,d}(t)\right), J\left(x_{2,d}(t)\right), \ldots, J\left(x_{i,d}(t)\right)\right) \quad (6)$$

Finally, forecasting the server room temperature using Jaya-NN algorithm is described in pseudocode in Fig. 4.

```
Start
Initialize candidate solutions described in Fig. 3 ;
For i=1 to number of candidates;
  Forward bias using eq (1) and eq (2);
  Evaluate candidates using eq (4);
End
Choose the best and worst candidate
While (termination condition is false)
  For i=1 to number of candidates
    For d=1 to D problem dimension
      Update new candidate using eq (3);
      Forward bias using eq (1) and eq (2);
      Evaluate candidates using eq (4);
    End
  End
 Update best and worst candidate;
End
Show best solution;
End
```

Fig. 4 Pseudocode Jaya-NN

In experimental, a 20 particle and 5000 iterations is used and compared with another intelligence optimization such as PSO.

IV. Result and Discussion

In this section, the performance of the proposed method is validated through the experiment in the same parameter and compared using PSO. Computation is using a core i5 3.2 GHz computer to compute the forecasting temperature data. The computation of forecasting is performed before showed all data to the website.

In the experiment, we captured the data from a sensor every three minutes — each data sensor sent to the gateway by the IEEE 802.11ac standard. The data sensor will be saved to the database, which provides the gateway where the gateway has a small storage. Sensor nodes will measure the temperature and humidity in a server room environment with several sensors described earlier.

The temperature fluctuation is measured in 24 hours a day. Then the logged data is computed in a PC web server while forecasting process is occurring. The forecasted temperature data and the actual temperature data is showed in Fig. 5. The performance of Jaya algorithm shows that forecasted data can match with the actual temperature data with 1.07 % of mean absolute percentage error in one hour ahead forecasted temperature data.

The performance of Jaya algorithm can be validated after the comparison with PSO. The PSO algorithm has 2.58 % of the mean absolute percentage error. Fig. 6 shows that Jaya-NN is outperforming with 1.49 % error less than PSO. The convergence speed of the proposed Jaya-NN is faster than PSO-NN around 500 iterations. Jaya-NN can find the best solution in 1150 iteration with MAPE is less than PSO; it can be seen in Fig. 7.

V. Conclusion

This paper discussed the forecasting of server room temperature through a sensor network. MLNN is used as a model to forecasting. The implementation of Jaya algorithm to learning the weight of MLNN has been formulated. The experimental shows that the implementation Jaya algorithm as the MLNN learning method has better accuracy and less parameter setting.

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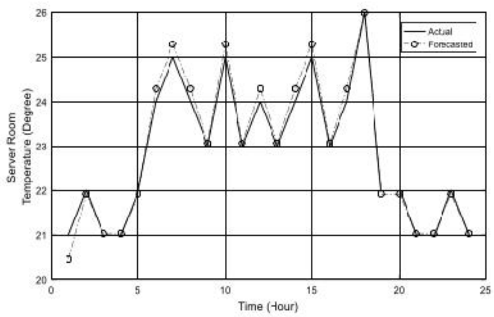

Fig. 5 The comparison between actual and forecasted data using Jaya-NN

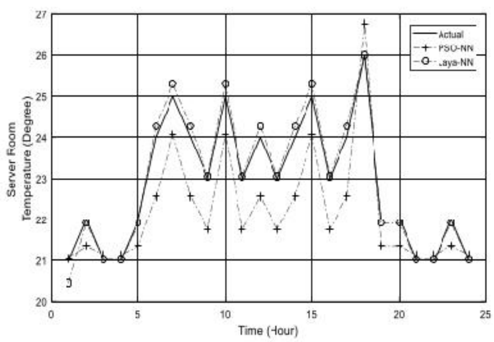

Fig. 6 The comparison forecasted data between Jaya-NN and PSO-NN in 24 hours.

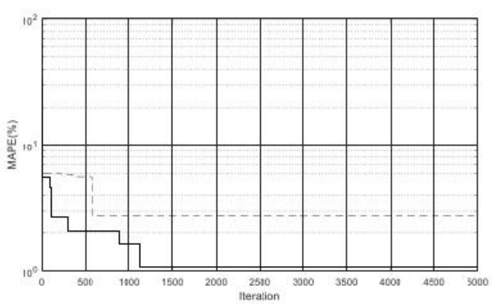

Fig. 7 Convergence Speed comparison between Jaya-NN and PSO-NN

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